

LUBRICANTS: FUNDAMENTALS OF TABLET MANUFACTURING

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ABSTRACT

Lubricants are those compounds which are useful to prevent adherence of tablet to the die wall, in turn would help tablet to easily eject from the die cavity. While compression shearing of harder material will be followed on to the softer material which would reflect the high shear force. Friction can be reduced by adding continuous film of lubricants to the moving surfaces or by boundary films. Fluid lubrication is not a surface phenomena and it would help in easy ejection of tablet but tackiness of the tablet and reduction of tablet strength are drawbacks of fluid lubricants. Boundary lubricants will help up to greater extent.

Keywords: Lubricants, Compression, Friction, Fluid lubricant, Boundary lubricant.

INTRODUCTION

Three interrelated groups of tablet excipients are glidants, anti-adherent, lubricants. These are used in tablet production to promote granule flow, prevent powder adhesion to punch faces and minimize die wall friction, respectively (Rawlins, 1977, Lachman et al., 1976). Some confusion exists in definition of a lubricant, as the word has also been used to encompass all three of above properties, due to suitable materials often possessing more than one of glidant, anti adherent and lubricant. It may be defined as a suitable material, a small amount of which interposed between two rubbing surfaces will reduce friction arising at the interface (Strickland et al., 1960; Komarek, 1967).

An ideal lubricant should reduce friction at small quantity. It should be inert and water soluble, colourless, odourless.

Tablet lubricants are those excipients added to the formulation which would help tablet to easily eject from the die cavity and would prevent sticking of tablet to die cavity as well. Without tablet lubricants tablets cannot be produced.

A lubricant should be capable of reducing wear on rubbing surfaces (silversher, 1969). To perform this function the lubricant must provide

film that will prevent solid to solid contact, and is easily sheared

(sentgen, 19710. Lubricants are added to tablet formulation primarily to reduce friction between die wall and granules as tablet is formed and ejected (sprowl, 1974; Lachman et al., 1970). The other main activities attributed to the lubricants are: (a) Prevention of sticking of granules to the tooling anti adherent; and (b) Improvement of granules flow property – glidant (Lachman et al., 1970). A given lubricant may provide one or more of these action to varying degrees but no one material is highly efficient in all categories (Sperandio and De machi, 1976; Strickland, 1959; Sprowl, 1974).

Accordingly combination of lubricants are often selected to provide the necessary total lubricant effect (Maly, 1963; Munzel and Kogi, 1954). Careful selection is necessary since some lubricants may interact adversely when in combination; for example, magnesium stearate and talc (de Blaey, 1972), although some authors have found that these two lubricants are compatible (Rubio, 1957; Esnaud et al., 1973) Although tablet lubricants have been used in practice for many decades it is only the last 15 years that the lubrication process has been studied fundamentally.

The Process of lubrication

When two solids in contact are displaced relative to each other and parallel to plane of contact, a resistance known as friction must be overcome (Bowden and Tabor, 1958; Bowden and Tabor, 1967). Surfaces are not smooth, but consist of irregularities known as asperities which are large compared to molecular dimensions.

(Fein, 1971) when two surfaces are brought together, they initially "touch" at points on highest asperities. Application of load causes deformation of the asperities initially elastically then plastically until the load is supported. It is at this point that the real contact area between two surfaces is established (Buckley and Johnson, 1972) for tangential motion to occur between the two surfaces. These interfacial junctions must be sheared. This is the welded junction theory of Bowden and Tabor (1958). This theory is applicable to tableting since sliding friction is involved as granules slide over each other and across die wall during ejection. Frictional resistance is interpreted as shearing of softer material by harder material riding over it. This can readily be seen in an inadequately lubricated granulation, because the tablets will bear vertical striations along their edges, reflecting the high frictional force of ejection along the die wall (Sprowl, 1974; Lachman, 1970). The total frictional force is given by (Buckley and Johnson, 1972; Bowden and Tabor, 1967):

$$F = SA$$

Where, F= frictional force.

S= shear strength of junction.

A=surface area in contact. the relative value assigned to friction of contacting surfaces is the coefficient of friction μ (Silversher, 1969).

$$\mu = S/W$$

Where, S= shear strength of junction and W=yield strength of softer material. The purpose of lubrication therefore is to reduce 's' by prevention of formation of welded junction by preventing asperity contact or by lowering the shear strength of junctions that are formed (Silversher, 1969). Lubrication can thus be achieved by the application of continuous film of lubricant to the moving surfaces or by boundary films, which do not totally cover the sliding surfaces.

In fluid lubrication the moving surfaces are completely separated by continuous film of lubricant itself (fig.1). Fluid lubrication is not a surface phenomenon. A fluid lubricant has a coefficient of friction of approximately 0.001 and wear is negligible. Boundary lubrication however is a surface phenomenon. The sliding surfaces are separated by lubricant films only a few molecules in thickness and therefore nature of underlying surfaces will affect the friction (Bowden and Tabor, 1967). The surface asperities support much of the load (Fig 2), friction coefficients are much higher, approximately 0.05-0.15, and wearing does occur (Fein, 1970). Boundary lubrication is provided by natural shear films, for example, water vapor contaminants or low shear strength lamellar solids (referred to as solid lubricants; for example, metallic stearates). Since the main function of a boundary lubricant is to interpose between the sliding surfaces, any film that is able to reduce the amount of surface tension and is itself easily sheared may be termed a boundary lubricant. The lubricant must however, have low shear strength, must be able to adhere to the surface to be lubricated and also be tough enough in film form.

To resist rupture and minimize wear (Carver, 1974; Buckley and Johnson, 1972), under boundary lubrication the load is supported over an area A (fig 3) by the lubricant film and by minute junctions formed where the lubricant film has been penetrated. The frictional force 'F' is the sum of the force required to shear the junction & the force to shear the lubricant film.

$$F = aAS + A(1-a) s_1$$

Where 'S' is shear strength of surface, S₁ is lubricant shear strength and 'a' is fraction over which junction formed for a good boundary lubricant, a is very small so that the major sliding resistance comes from shearing of the lubricant itself hence the low shear strength requirement (Bowden & Tabor, 1967).

Strickland (1959, 1960) was the first to attempt to correlate general lubrication theories to the behavior of lubricants in tableting hydrocarbons such as mineral oil were stated to be examples of fluid type lubricants being dependent upon viscosity for their effectiveness. They lubricated the die wall and prevented seizures of the two surfaces in proportion to their ability to maintain the continuous layer.

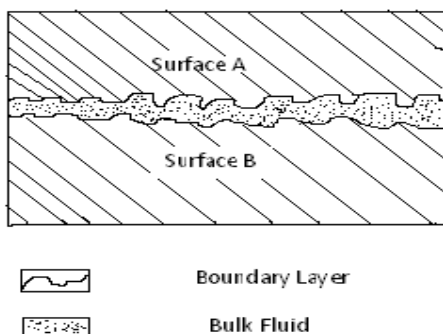


Fig. 1: Fluid Film Lubrication of Two Surfaces

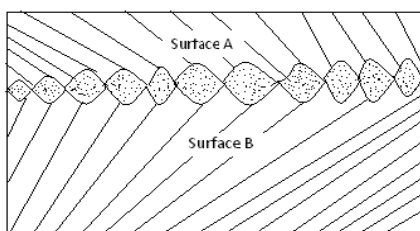


Fig. 2: Boundary Film Lubrication of Two Surfaces

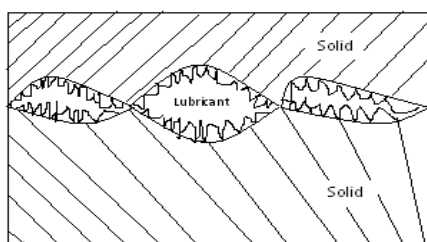


Fig. 3: Mechanism of Boundary Lubrication

Between the surfaces the main problem with fluid lubrication was the increase in tackiness (reduction in the rate of granule flow) and a reduction in tablet strength (Lachman et al 1970; Salpekar, 1975). Boundary lubricant results from the adherence of polar portions of molecules with long carbon chains to the opposing surfaces, for example magnesium stearate. The latter type is most commonly used in tableting because it is more effective

requires smaller quantities and is more easily applied to granules (Strickland, 1959). From his study, Strickland (1960) concluded to be generally amenable to the theory of lubrication reported for other systems.

Theory and mechanism of action of lubricants

Based on Bowden and Tabor theory of friction the shear strength theory is now the most commonly accepted mechanism of lubrication with respect to tableting. This shear strength theory suggests that the frictional force at the tablet die wall interface results from the shearing of junctions between the tablet and wall material (Lachman et al., 1970). Thus the lubricant is thought to offer a lower shear interface than that characteristic of the die wall tablet surfaces and will thus readily shear when tangential motion is initiated between the tablet and die during the ejection process (Strickland, 1959). Shear strength values for various lubricants have been measured by Train & Hersey (1960) using a punch penetration test. Scruten et al (1972) measured the shear strength of calcium stearate monolayer and multilayer and other material and concluded that shear strength could not be simply interpreted in terms of molecular structure and orientation, but was perhaps more closely related to bulk rheological properties even though the film may be only one or two molecules thick. This view was supported by Jentgen (1971) who concluded that lubrication for solids cannot be ascribed to any one property of the materials; thermal and oxidative stability, chemical reactivity, mobility, hardness and crystal structure all affecting lubricant function and performance. Use of shear strength measurements to evaluate lubricants has been attempted by Lewis and Shotton (1965) and Lewis and Train (1965), but they found no correlation between lubricity and shear strength. Boundary films can be chemisorbed (Allen and Prauglis, 1969) and these type of films are most suitable for boundary lubrication because of the strong adherence to the surfaces to be lubricated (Buckley and Tabor, 1958). Next in order of lubricant ability are physically adsorbed films provided by polar molecules on non-chemically reactive surfaces. Adhesion is not as strong but lateral cohesion is high. Adsorption of non-polar molecules on a metal substrate is usually very weak since adhesive and cohesive forces are small (Allen & Prauglis, 1969). However the latter has been reported to be more effective than a fatty acid or soap above its

melting point (Rabinowicz and tabor, 1951). Thus metallic soaps are effective boundary lubricants because they have high melting points and suitable shear properties.

Another mechanism of lubrication has been proposed by Wolff et al (1947). These workers suggested that a lubricant might act as a conductor of static electricity

By providing more points of contacts which in turn would reduce the high charge build up during the rapid compression of some compounds. Work by gold and Palermo (1965a) showed that magnesium stearate and talc reduced the static charges generated by flow of particles through a hopper. The authors carried out a further study on the anti static properties of the tablet lubricants themselves (Gold and palermo, 1965b). Magnesium stearate, polyethylene glycol 4000, Sodium lauryl sulphate and talc had the ability to lower accumulation of static charges. The antistatic properties decreased with a decrease in lubricant concentration and were independent of material accumulating the charge. A similar behavior for magnesium stearate was also reported by Bhatia and Lordi (1979).

Thus although many theories abound to explain the mechanism of lubricants, including an electron distribution theory of jumison (1972, No one theory explains completely how a lubricant functions in prevention friction. It would seem that as newer materials are evaluated as lubricants, a clearer picture of their mode of action will evolve.

CONCLUSION

Tablet lubricants are those crucial components of oral solid dosage form which prevents adhering of granules to die wall. Lubricants also helps tablet to get rid of various defects like lamination, sticking, chipping. Mode of action of lubricants follows different ways but here in this review article it has been explained with the help of Surface lubrication and boundary lubrication. Lubricants creates a film layer in between die wall and granules. When the lubricant is thought to offer a lower shear interface than that characteristic of the die wall tablet surfaces and will thus readily shear when tangential motion is initiated between the tablet and die during the ejection process.

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